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AD

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DEVELOPMENT OF A RECOVERY BODY FOR THE AMRAD PROJECT

by
H. C. Tom

August 1965

U S ARMY MISSILE COMMAND
REDSTONE ARSENAL, ALABAMA

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Mechanical and Electrical Design Branch
Structures and Mechanics Laboratory
Directorate of Research and Development
U. S. Army Missile Command
Redstone Arsenal, Alabama

ABSTRACT

This report describes the design and development of the AMRAD Target Project, Experiment I, recovery body which is used to return a tape recorder containing valuable research data from a suborbital missile flight flown to investigate radar re-entry phenomena.

Both impact-type bodies utilizing no deceleration devices or location aids and parachute-type recovery bodies were evaluated. The final design was a recoverable nose cone utilizing a colored, radar-reflective, metallized parachute, a radio beacon, and a flashing light (for night missions) as recovery aids. High-altitude drop tests from 45,000 feet under nighttime conditions confirmed the workability of the design.

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Section I. INTRODUCTION

The AMRAD Target Project is one of the Advanced Research Projects Agency's (ARPA) projects organized to study the nature of missile re-entry as it affects radar measurements. To remedy the deficiencies of present anti-missile missile systems, a new concept was developed known as ARPAT or Advanced Research Projects Agency Terminal. AMRAD, or ARPAT Measurement Radar, is designed to make detailed studies of re-entry vehicles having a variety of known characteristics and parameters. It has the additional function of developing and testing radar-generation and signal-processing techniques.

The AMRAD Target Project objectives are twofold: 1) to provide suitable targets or re-entry test vehicles (RTV) for the AMRAD system, and 2) to provide re-entry physics and research data.

Flight and other research data are telemetered to ground stations by means of onboard telemetry during most of the flight. However, since continuous RF transmission cannot be guaranteed at re-entry altitudes where there is considerable aerodynamic heating to the skin of the RTV, resulting in the formation of an ionized plasma sheath, this data must be made available by other means. Two methods were suggested: 1) the use of tape-recorder playback after the critical altitude had been traversed, and 2) recovery of the tape recorder by means of a recoverable capsule or nose cone. The second method was chosen as the best of the two approaches, since there was insufficient time for tape playback before the body would experience structural failure due to aerodynamic heating.

Section II. BACKGROUND

In early 1962, ARPA requested the Directorate of Research and Development of the Army Ordnance Missile Command (now Army Missile Command) to make a concentrated 6-week engineering study to determine the specifications for the AMRAD Target Experiment payloads and perform a feasibility evaluation of the AMRAD Target Project.[1]

The AMRAD Target requirements as stated in the report of the 6-week study included instrumentation for Experiments I, III, VII, VIII, and IX. Investigation at that time visualized the tape recorder in an insulation-coated aluminum sphere for data recovery. The sphere would be released upon destruction of the missile body structure by aerodynamic heating at approximately 100,000-feet altitude. Figure 1 is a sketch of the early concept of the recovery body. Protection of the tape recorder and tape at impact would be provided by molded foam plastic. Figure 2 illustrates the re-entry body concept of Experiment I with the protected tape recorder.

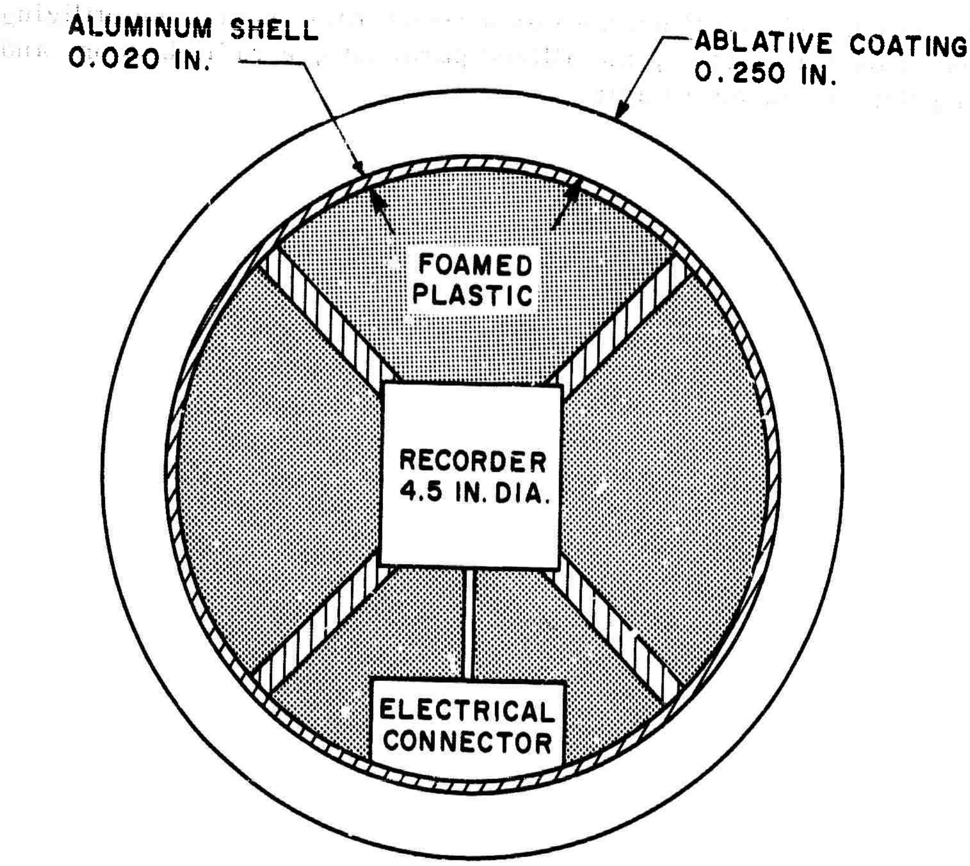
The AMRAD targets are to be boosted from Green River, Utah, into White Sands Missile Range (WSMR), New Mexico, a distance of approximately 450 miles.

The first- and second-stage motors boost the fourth-stage RTV to an altitude of about 600,000 feet and to a velocity almost equal to the experimental velocity, with direction and re-entry angle controlled by the guidance system. Experimental velocity is attained by the RTV motor. Burnout of the RTV motor must be at least 4 seconds prior to the time the payload reaches the test level of 300,000 feet to prevent motor outgassing from affecting the radar experiment.

Separation of the recovery body occurs at 100,000 feet, which is the lower level of the test region. Figure 3 is a typical trajectory when a parachute is used to decelerate the recovery body.

The Mechanical and Electrical Design Branch of the Structures and Mechanics Laboratory, Directorate of Research and Development, with support from other laboratories, was assigned the task of designing and developing a recovery body in which the recording tape, with its valuable data, can be recovered quickly and safely.

This report describes the development of the AMRAD Target Project, Experiment I, recovery body. Both impact-type bodies utilizing no deceleration or location aids and parachute-type recovery bodies were evaluated. The final design was a recoverable nose cone utilizing a colored, radar-reflective, metallized parachute, a radio beacon, and a flashing light as recovery aids.



SPHERE DIAMETER	9.0 IN.
SPHERE WEIGHT	7.0 LB.
ABLATION:	3.8
SHELL:	0.2
RECORDER:	3.0

Figure 1. Early Concept of the AMRAD Recorder Recovery Sphere

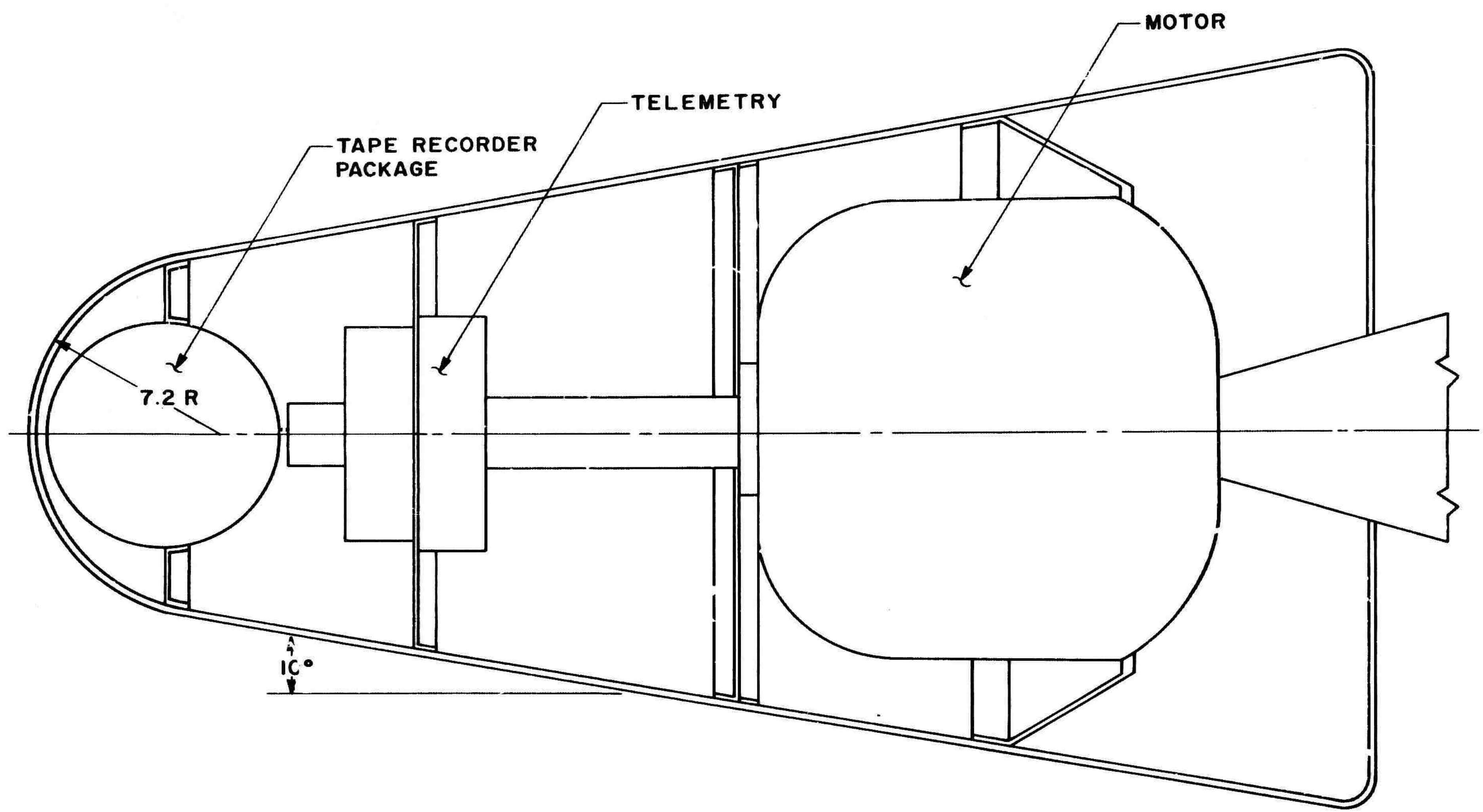


Figure 2. AMRAD Target Project, Experiment I, Re-entry Test Vehicle (RTV)
Showing Protected Recorder Recovery Sphere

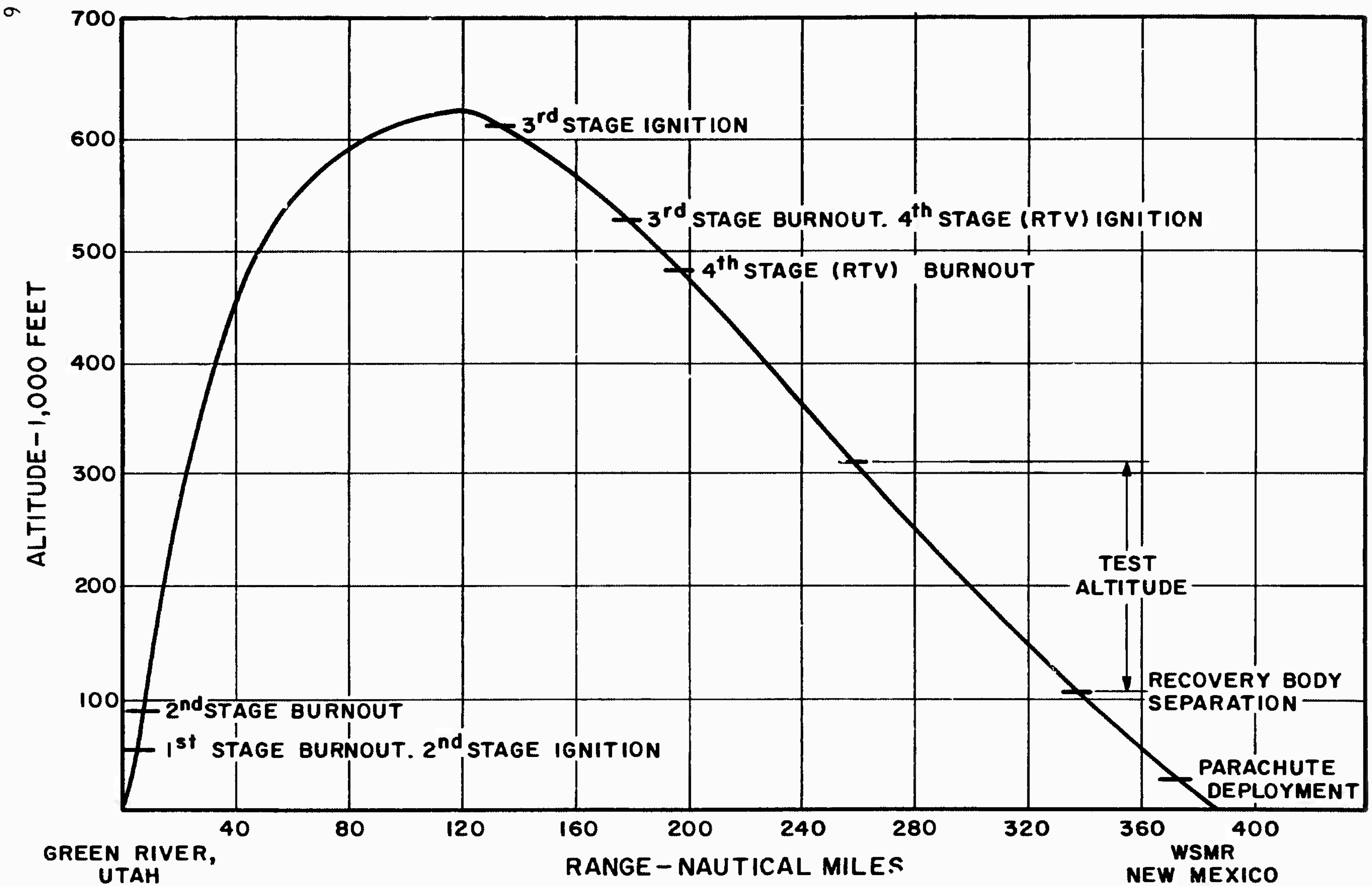


Figure 3. Typical AMRAD Target Trajectory

Section III. DESIGN AND DEVELOPMENT - PHASE I

Phase I of the design and development process was a feasibility study of the recovery capsule suggested by the 6-week engineering study conducted by the Research and Development Laboratories. As mentioned in the previous section, this capsule consists of an insulated sphere containing the tape recorder which would be released upon destruction of the RTV body by aerodynamic heating at approximately 100, 000-feet altitude. Other capsule configurations based on the same method of release from the RTV also were evaluated.

1. Preliminary Requirements

The design of the capsules was based on the following preliminary requirements:

a. Recording Tape.

The recording tape must be recovered in a readable condition. The survival of all other capsule components, including the tape recorder, is not required.

b. Mission.

The AMRAD Target will be flown in a night mission.

c. Recovery Location.

Termination of the AMRAD Target flights will be in WSMR. The ground altitude at WSMR is approximately 4, 000 feet (mean sea level).

d. Recovery Time.

Desired recovery time is not more than 24 hours. This limit is governed by the length of time that the recording tape is estimated to be able to withstand desert-summer climatic conditions.

e. Separation Altitude.

Since 100, 000 feet is the lower limit of the test altitude, separation of the capsule from the RTV is desired at or below this altitude.

f. Velocity at Separation.

20,000 fps.

g. Re-entry Angle of the RTV.

23° ±3°.

h. Internal-Temperature Limit (capsule).

220°F.

i. Spin of RTV at Separation.

3 to 5 rps.

j. Acceleration.

5 g's laterally and 30 g's longitudinally.

k. Deceleration.

90 g's.

2. Spherical Recovery Capsule

It became readily apparent that this configuration was not feasible because survival of the tape could not be guaranteed, and that locating a small recovery body after impact was highly unlikely in the expected impact area at WSMR.

The tape recorder to be used was heavier (5.5 pounds) and bulkier (4.25-inches diameter by 5.75 inches) than originally visualized. Since the largest sphere that could go into the available space was only a 9.5-inch-diameter sphere, the recorder could not be sufficiently protected from the impact forces. Also, space was not available for a parachute-deceleration system to be incorporated.

To further compound the problem, the impact point on the sphere could not be controlled unless excessive ballast was added. For maximum probability of tape survival, the recovery body should impact in such a manner that the end of the recorder containing the tape is the furthest from the impact point. Thus, the recording tape would not be destroyed at impact from the crushing effect of the mass above it.

Other designs of the spherical recovery body were investigated in which excessive ballast was necessary to make the body stable in the right direction. However, it was not pursued too strenously, since the probability of locating it after impact was small, even if the tape survived, due to the type terrain at the expected area and the vastness of the area. In the past, much larger objects have been lost for days - and some not even found - even though the general impact area was known. Consequently, the spherical recovery body was dropped from further consideration.

3. Cone-Frustum Recovery Capsule

Paralleling the investigation of the spherical recovery capsule was the investigation of the cone-frustum recovery capsule. The use of this configuration made it possible to utilize the maximum amount of the available space in the nose section of the payload stage. Thus, more space was available for the incorporation of a shock-absorbing system, streamer location aid, or a parachute-deceleration system.

The cone-frustum recovery capsule would be released from the parent body in the same way as the spherical recovery capsule; that is, by destruction of the parent body from aerodynamic heating. Three designs of this configuration were drawn up: 1) impact body, 2) impact body with streamers, and 3) parachute-decelerated body.

4. Low-Altitude Drop Tests

Four low-altitude, aircraft drop tests were conducted at WSMR to determine whether the cone-frustum recovery body configuration was feasible. Four small nose cones having similar aerodynamic characteristics as the proposed body were used for the tests. The purposes of the tests were as follows:

To determine whether the recovery body would bury itself upon impact on terrain similar to that at the expected AMRAD impact area of the actual shot.

To determine the damage sustained by the recording tape upon impact.

To check out the effectiveness of balsa wood as a shock-absorbing medium.

To check out the effectiveness of a colored streamer as a locating aid.

To check out the effectiveness of the cover plate as a deceleration device.

The first two bodies each contained two spools of mylar recording tape placed in simulated tape recorders. One inch of balsa wood was placed underneath the simulated tape recorders to cushion them upon impact of the recovery body. The selection of balsa wood was based on Jet Propulsion Laboratory tests of various shock-absorbing materials in which balsa wood was found to have the highest energy-absorbing capability among the materials tested.[2] Other materials tested included styrofoam, eccofoam, epoxy foam, and aluminum honeycomb.

As a location aid for the air and ground recovery crews, a 3-inch-wide, 10-foot-long, orange streamer was attached to the cover of each cone.

The nose cones were dropped from a helicopter from an altitude of 5,000 feet above ground, in two different areas, so that impact would occur in soft sandy soil and in firmly packed soil. Impact velocity was to be about 250 feet per second.

Results of the first two drop tests showed that the most difficult problems would be location and recovery after impact.[3,4] The orange streamers were ineffective as location aids. Even though observers were in the immediate drop area, the nose cones could not be located in the air by means of the streamers. On the ground, the streamers could not be readily spotted from the air.

The first drop test was made in the area of firmly packed sand (alkali flats), with little vegetation. Recovery of the nose cone was made within 15 minutes. The second drop test was made in an area where the sandy soil was relatively soft and terrain was dense with mesquite bush. This area was more like the actual AMRAD impact area. Although the immediate drop area was known, recovery of the cone was not made until more than 3 days later. Location of a small cone among the low-lying bush was mostly by chance. In the actual flight test, this area would be considerably wider and location would be almost hopeless.

Structurally, the nose cones and their internal structures were not damaged or deformed to any noticeable degree, even where impact was on the firmly packed sand. In this area, the nose cone made a crater about $1\frac{1}{2}$ inches deep. In the soft sandy soil, the nose cone made a crater about 3 inches deep.

The recording tape and spool were undamaged. Playback of the tape showed that it could be expected to survive in an impact body, even if lost in the WSMR summer-desert environment for 3 days.

The third and fourth drop tests were made to check out the design utilizing the cover plate as a drag device to decelerate the nose cone in its descent. An aneroid switch was used to fire the thrusters which ejected the cover plate at the desired altitude. The test goals were not realized in these two tests. In the third test, the cover plate was folded diametrically together by the force of the thrusters, and in the fourth test, the safety pin in the firing circuit failed to disengage as the body was dropped from the helicopter. However, these two tests again emphasized the difficulty of locating a small recovery body in this type terrain.

It was concluded from these tests that other location aids besides streamers must be incorporated into the recovery body so that the exact impact point can be determined quickly or, at least, the search area can be narrowed down to a reasonable area that ground and air search crews can cover thoroughly in a short time.

Section IV. DESIGN AND DEVELOPMENT - PHASE II

Up to this period in the development of the recovery body, the release of the recovery body from the parent RTV was dependent on the uniform selfdestruction of the RTV by aerodynamic heating. Based on this concept, the development process was simplified, since no mechanical-separation system was required.

A closer thermodynamic study indicated that this concept was not feasible because the complete and uniform destruction of the RTV could not be certain. In this case, it is possible for the recovery capsule to be released in a tumbling attitude which would be undesirable. Furthermore, it is conceivable that the recovery capsule could become "hung up" on the motor, which is expected to survive to impact and be destroyed.

Thus, design of the recovery body proceeded to a new concept which utilized the insulated nose section of the RTV as the recovery body. Separation of the nose section would be accomplished by means of a linear shaped charge prior to destruction of the rest of the RTV by aerodynamic heating.

The final design of the recovery body was affected by many factors. Among the most important of these factors were: 1) radar requirements, 2) the need for recovery aids, 3) heating problems, 4) separation problems, 5) trajectory, and 6) safety. Also, as in most cases of missile design, the problems of limited space and weight allowable were present.

1. Radar Requirements

Fabrication and assembly methods for the RTV were mainly dictated by the radar requirements.

The radar cross section of a target is a measure of the efficiency of the scatterer (target) in re-radiating or returning energy to the radar. It is a function of the shape, size, and composition of the target, and other external factors such as transmitted frequency and polarization. Any discontinuities in the surface of the scatterer such as joints, cracks, holes, slots, or sharp breaks in the plain surface affect the radar cross section of the target, so that a true reading for a particular body configuration cannot be obtained. Therefore, the finished RTV was required to be a one-piece body having a smooth skin surface without any of the abovementioned discontinuities.

These requirements affected the recovery-body design in the following manner:

To make the RTV free of discontinuities, the nose section (spherical cone) and the body section (frustum), although fabricated and formed separately, must be welded together prior to coating the body with insulation material.

For ease of assembly, the components of the recovery body must be mounted on a mounting ring to form a one-piece package which can be attached to a mating mounting ring on the RTV body. This also means that the recovery package must be assembled into the RTV prior to the installation of the telemetry package and the solid-propellant motor. Conversely removal of the recovery package after the RTV has been assembled requires removal of the motor and telemetry package first.

2. Recovery Aids

The low-altitude drop tests conducted at WSMR emphasized the need for incorporating locating aids into the recovery body, especially if the tape is to be recovered within 24 hours after impact so that tape deterioration due to heat cycling can be kept at a minimum.

A number of methods to aid in locating the recovery body during descent or after impact were suggested. Of these, three aids, the radar-reflective parachute, flashing light, and radio beacon, were selected for use. The combination of these three aids fulfilled the requirements for ease in locating the recovery body in a night mission more than any of the other methods suggested.

A metallized parachute would provide a highly reflective target for radar acquisition, and the fact that the target is a relatively slowly descending one enhances the probability of acquisition.

In a night mission, a high-intensity flashing light can be seen in flight by airborne personnel in the immediate area. More important, the flashing light could be more easily detected after ground impact of the recovery body. This, of course, would be true only if the flashing light is not covered by the collapsing parachute immediately after impact. However, because of the almost-constant ground wind in the expected area at WSMR, it is likely that the parachute will be stretched out to its full length along the ground, leaving the flashing light uncovered.

The radio beacon would serve as a redundant locating aid. Power can be switched on at the same time that the parachute is deployed, and the beacon can operate for several hours after ground impact of the recovery body.

Some of the methods that were suggested and discarded were: the use of a dye marker, smoke marker, radio isotape beacon, sound device, and dog-sensitive scent.

The following paragraphs discuss the details of the metallized parachute, flashing light, and radio beacon.

a. Parachute.

The parachute selected was a 9-foot-diameter extended-skirt parachute with alternate gores colored orange and black as a visual aid in case day recovery is necessary. The orange gores were treated in a metallizing process to make them radar reflective.

Selection of the parachute size and type was based on the space available of approximately 170 cubic inches and the desired impact velocity of 40 to 50 feet per second. The parachute pack, not including the riser straps, bridle straps, and swivel, is hand packed into a pack in the shape of a thick-wall hollow cylinder.

A reefing line was also provided with the parachute to prevent the parachute from fully opening until it is completely extended. Keeping the parachute reefed in this manner reduces opening shock loads since drag forces are applied more gradually. The reefing line is cut by a reefing-line cutter as the parachute becomes fully extended.

To prevent entanglement of the shroud lines due to spinning of the recovery body, a swivel was used between the risers and the shroud lines.

Figure 4 illustrates the parachute in the packed condition with its risers, bridles, and swivel.

b. Flashing Light.

The main requirements of the flashing-light system were that visibility be from 4 to 6 miles and that the flashing rate be from 40 to 60 flashes per minute.

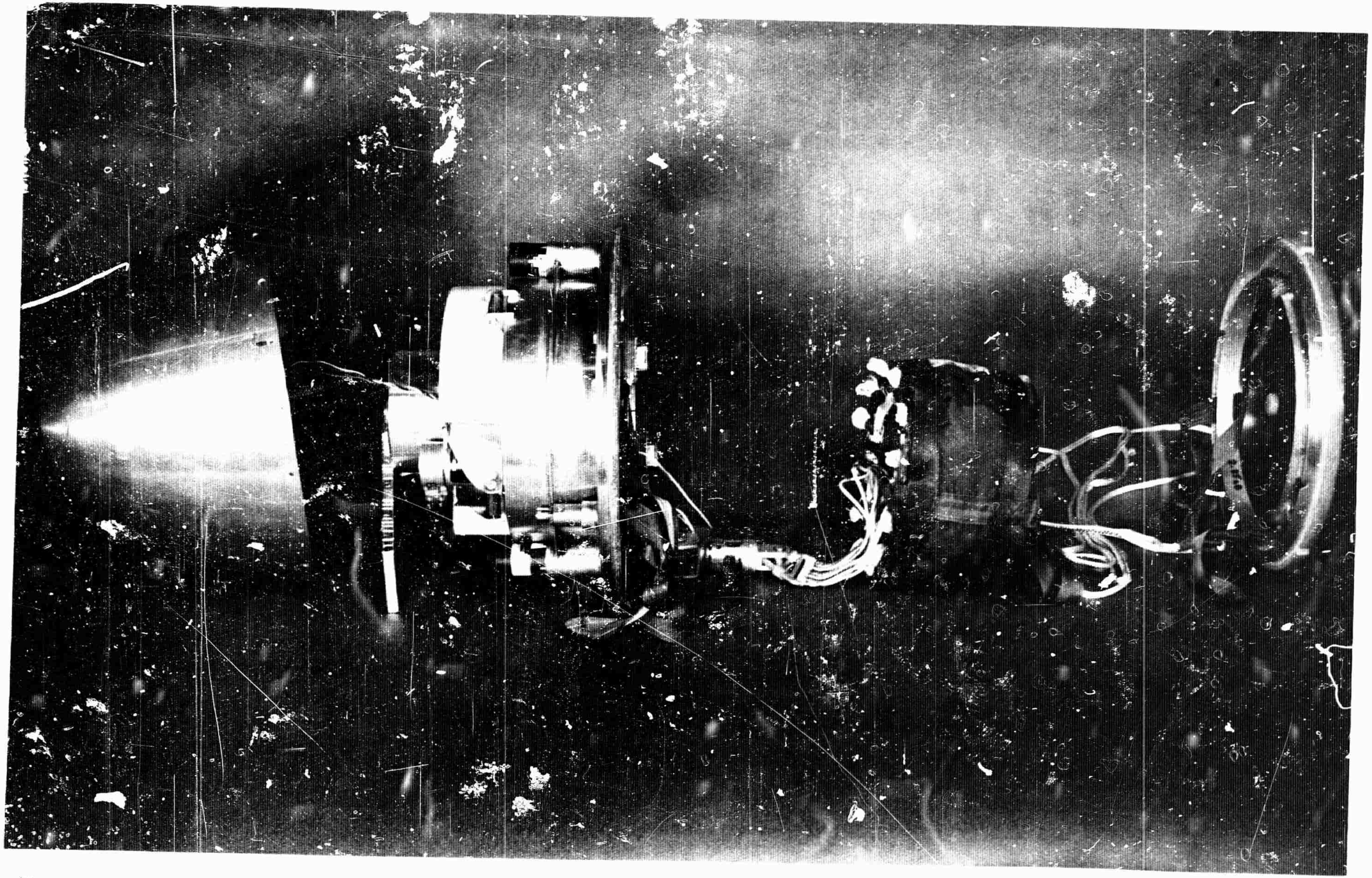


Figure 4. AMRAD Target Project, Experiment I, Recorder Recovery Body, Exploded View

Two number 12 General Electric bulbs were placed in the parachute swivels, which were modified to provide window cut outs. The flasher electronic unit consisted of a transistorized oscillator with a transistor-diode amplifier to increase the intensity of the flash. The flasher unit was encapsulated in potting compound to provide a small, compact, and rugged unit.

Power to operate the flasher system was supplied by the nickel-cadmium batteries used also to fire the thruster-power cartridges. Control was through a miniature DPDT relay connected to the mechanical timer, which also timed the firing of the cartridges.

Figure 5 shows the flasher-system components and Figure 6 is a diagram of the flasher electronic-unit circuit.

c. Radio Beacon.

The radio beacon chosen was one operating on a frequency of 1600 Mc made by the Lexington Army Depot. Except for the configuration, this beacon was similar to one used in the Meteorological Rocket Project at WSMR. Power was provided by batteries encapsulated in polystyrene foam for protection against extreme temperatures. A $1\frac{1}{4}$-inch pop-out antenna ($\frac{1}{4}$-wavelength dipole), which also served as the power switch, extended when the recovery body back-cover plate was kicked off at the start of parachute deployment. Receiving equipment consisted of existing AN/GMD-1 directional receivers at WSMR, and location was by triangulation.

3. Separation

a. Separation Signal and Altitude.

The method of initiating the nose-cone separation signal and the altitude at which separation should occur was determined from trajectory and aerodynamic-heating studies. Two methods were considered to initiate the separation signal: 1) use of a timer switch based on time from a given event such as RTV (fourth stage) separation, and 2) use of a g-switch based on increasing deceleration due to re-entry drag forces. Separation was desired at or below the lower level of the test altitude (100, 000 feet) and above the altitude at which the RTV after-body would begin to weaken by excessive aerodynamic heating.

Three trajectories were run and the results plotted with deceleration versus altitude and time versus altitude. The trajectories were based

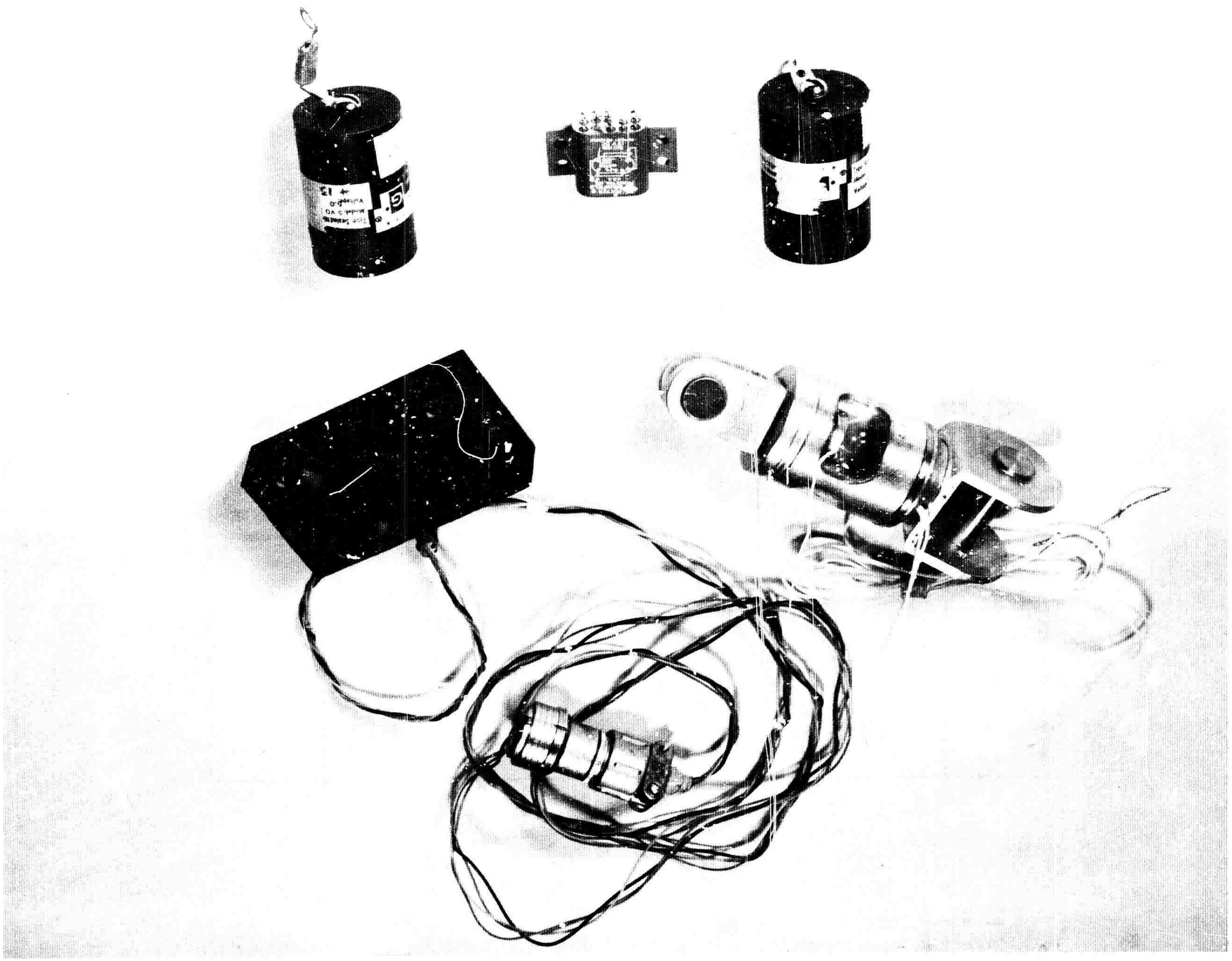


Figure 5. Flashing-Light System Components

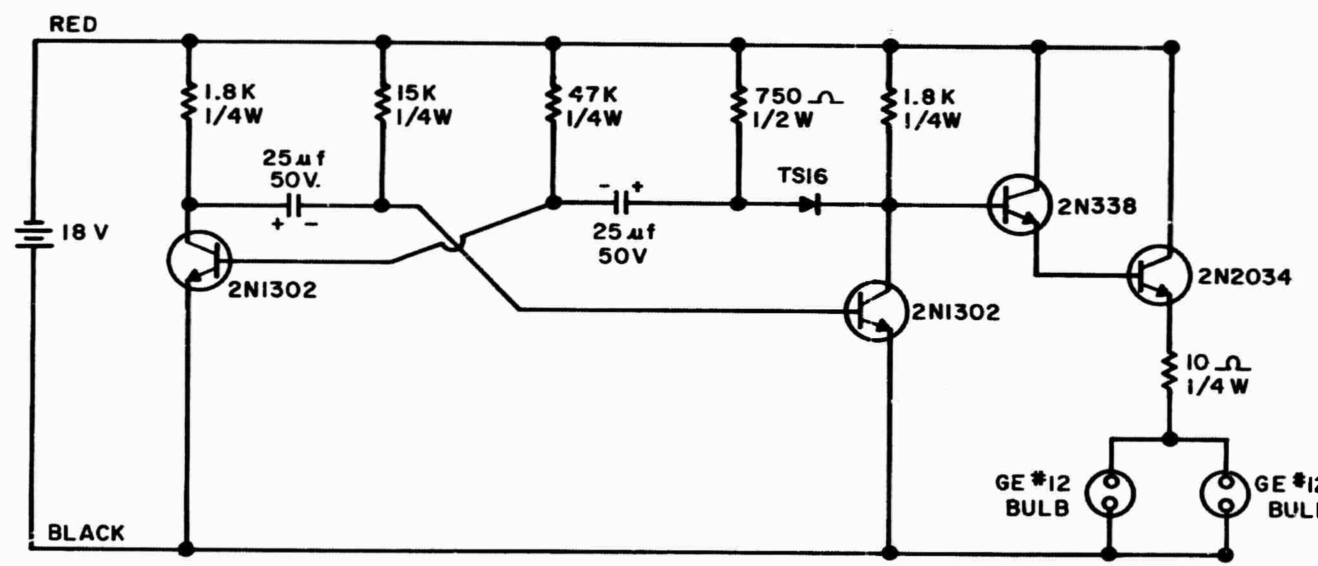


Figure 6. Flashing Light System Circuit Diagram

on values defined as a 2-sigma variation for re-entry velocities and a 3-sigma wind profile. The density variation for a mean summer day and mean winter day was from the 1962 Standard Atmosphere.

Table I lists the values used for the standard, minimum, and maximum deceleration trajectories.[5]

Table I. Parameters for Standard, Minimum, and Maximum Deceleration Trajectories

Parameters	Trajectory Values		
	Standard	Minimum Deceleration	Max. Deceleration
Velocity	V	96-percent V	104-percent V
Re-Entry Angle	θ	θ +3°	θ - 3°
Ballistic Coefficient	β	110-percent β	90-percent β
Wind Direction	No Wind	Tail Wind	Head Wind
Density	d	Winter Day (low)	Summer Day (high)

Based on the trajectory study, real-gas aerodynamic-heating effects were calculated for the aft end of the RTV.

Figures 7 through 9 show the Experiment I trajectories and temperature-history curves.[6]

A g-switch was selected to initiate the separation event, and the nominal or desired altitude was selected at 105, 600 feet to ensure that separation would occur before destruction of the aft section under the most conservative variation of the standard trajectory.[7] A switch point of 31 ± 1 g's was recommended and the resulting altitudes computed as shown in Table II.

Table II. Separation Altitudes for Variations of the Standard Trajectory

g's	Separation Altitude (feet)		
	Max. Dec.	Standard	Min. Dec.
30	115, 000	106, 600	98, 900
31	113, 500	105, 600	97, 700
32	112, 500	104, 300	96, 500

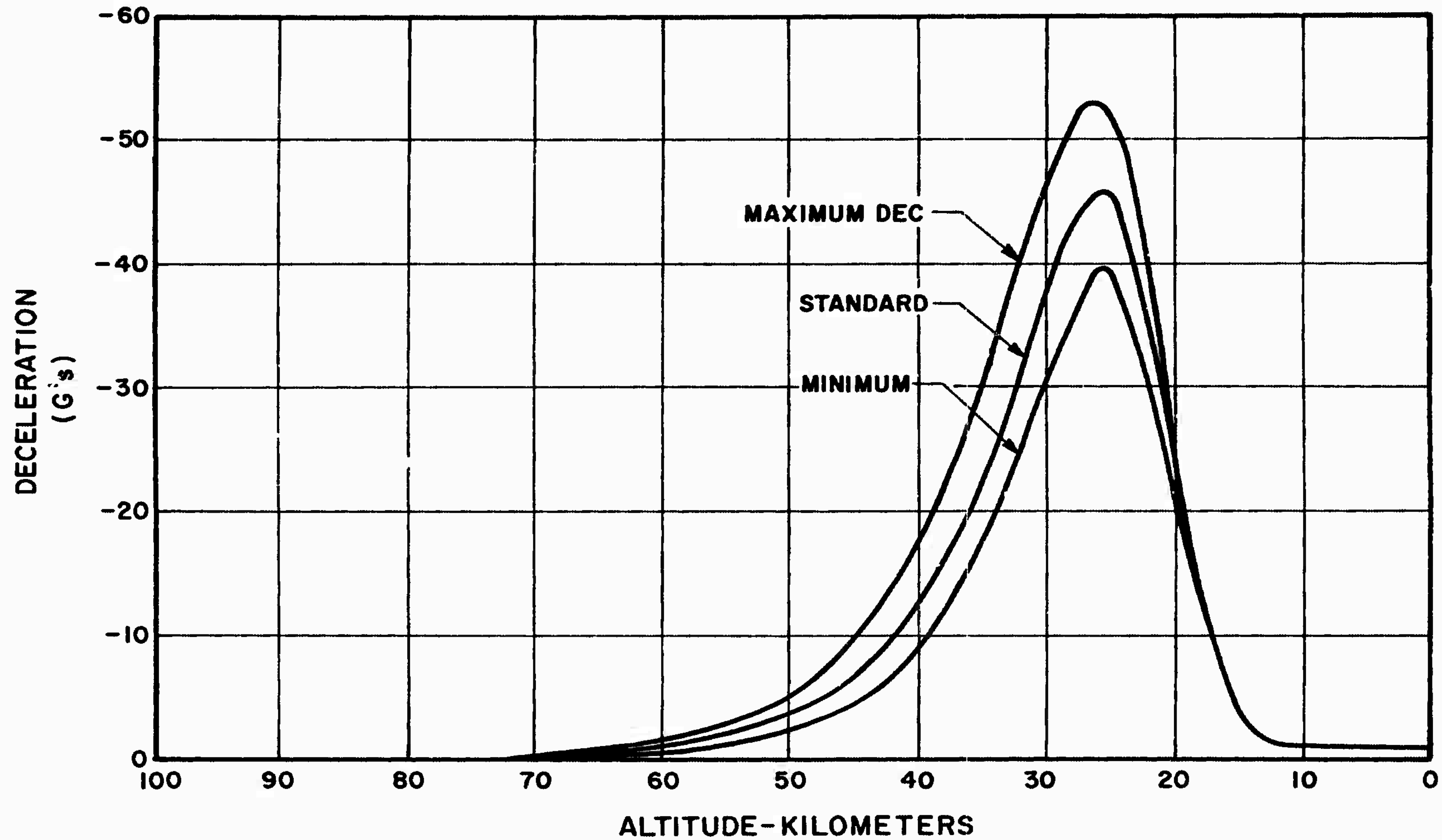


Figure 7. Trajectories for Maximum, Standard, and Minimum Deceleration Re-entry Conditions, Deceleration versus Altitude

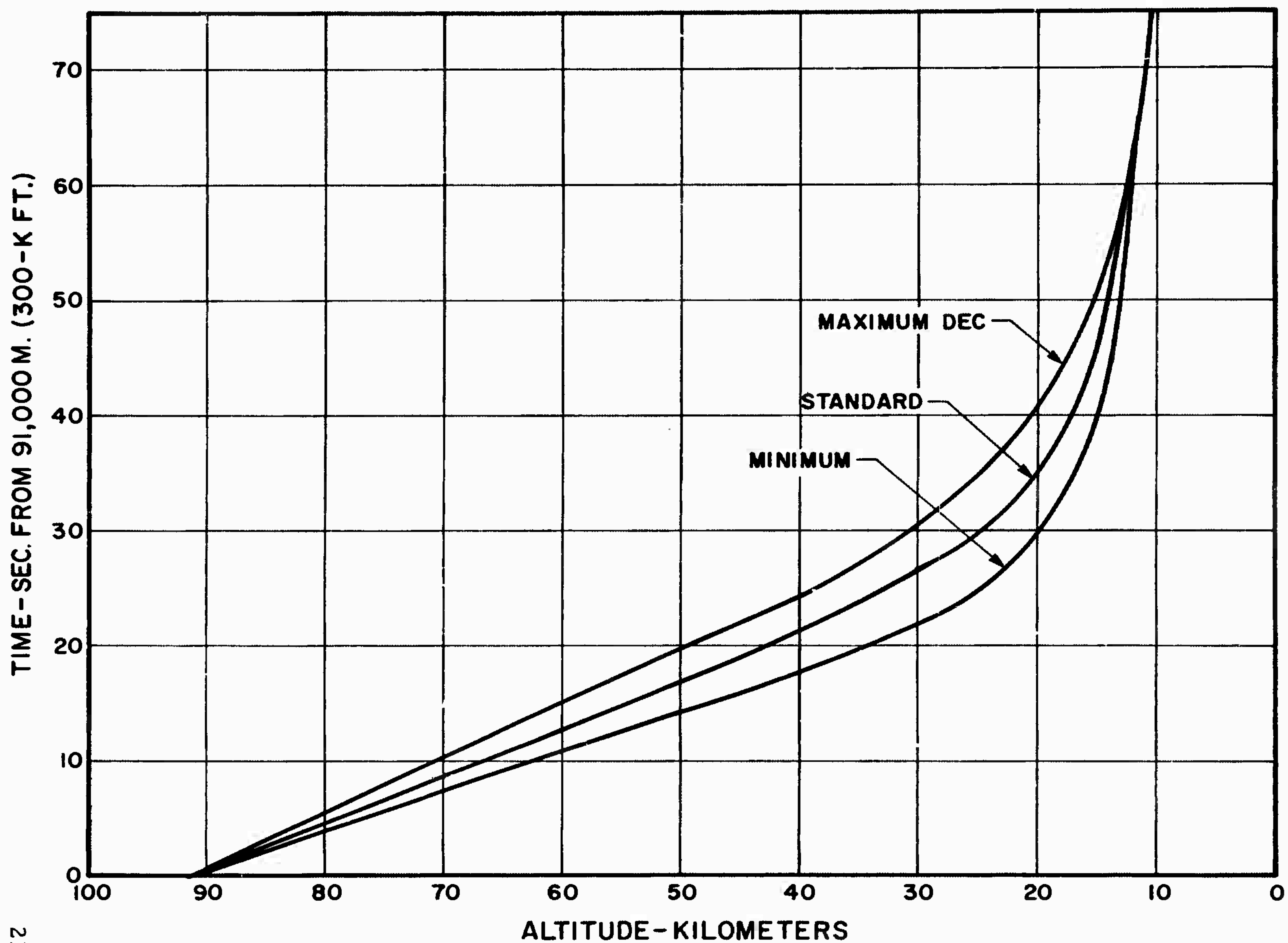


Figure 8. Trajectories for Maximum, Standard, and Minimum Deceleration Re-entry Conditions, Time versus Altitude

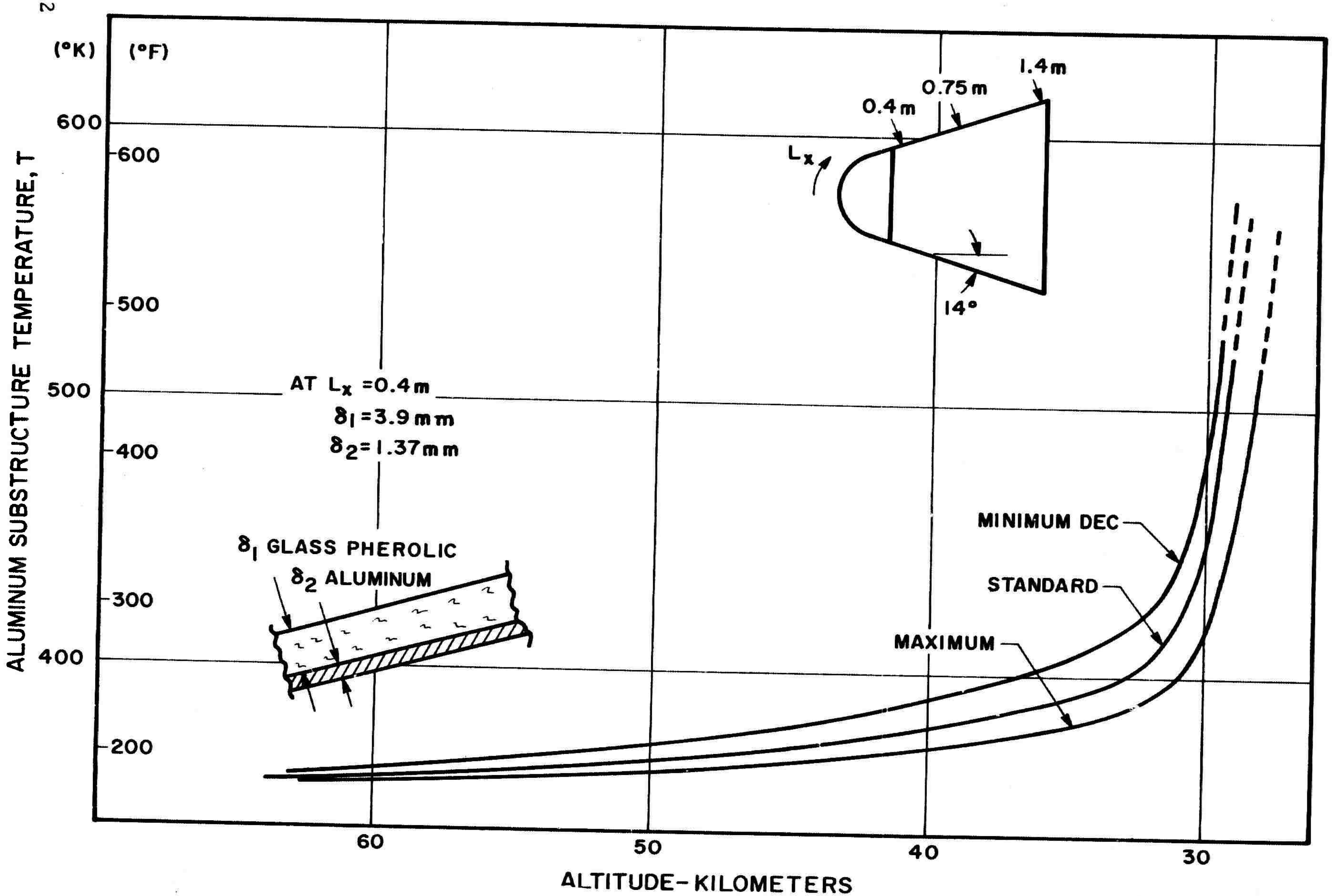


Figure 9. Calculated Substructure Temperature Histories for Forward Station of RTV Afterbody

b. Separation Method.

To separate the nose-cone recovery body from the rest of the RTV (afterbody), a flexible, linear shaped charge will be used to make a circumferential cut of the missile insulated skin.

In the tests that were made to determine the correct size of the shaped charge, it was found that cutting the 0.054-inch 5052-O aluminum alloy substructure presented no problem. Difficulty was experienced in making a clean cut through the approximately one-half inch of lap-wound glass phenolic insulation. The metal skin could be cleanly cut with only a 5-grain RDX shaped charge. However, even with a 50-grain shaped charge, the insulation could only be shattered in places. The cushioning effect of the comparatively low density insulation prevented the jet blast of the shaped charge from making a clean cut.

Since it was not desirable to use a more powerful shaped charge because of the possible damage to the recovery-package components by shock and blast effects, a sealed, machined joint at the separation line was designed into the insulation coating. Figure 10 illustrates this joint. The nose section is first wrapped up to the separation line, then machined back at an angle of 60 degrees. The remainder of the RTV is then wrapped, with the joint filled with resin as the wrapping progresses.

Subsequent tests using 5- and 7-grain shaped charges on this joint proved successful. Even though ablation of the insulation surface might cause the joint to become welded together at the surface, the shock provided by the shaped charge will be sufficient to break the joint cleanly.

c. Separation Distance.

Trajectory studies indicated that at the time the nose cone is cut at 100,000-feet altitude, the drag-weight ratio for the recovery capsule is approximately two times as great than for the aft body.[8] Assuming that the two bodies will remain in close contact with each other, natural separation should occur at an altitude of 55,000 feet, when the velocity of the two bodies has decreased to about Mach 2. This action is graphically illustrated in Figure 11. This is the likely case for another experiment. However, for Experiment I, the afterbody is designed to survive to 100,000 feet, with probable failure at about 85,000 feet. If the afterbody fails in a manner to produce high angles of attack ($\alpha > 30°$), then the capsule will separate and most likely tumble.

Two approaches were followed to solve this problem. The first approach included initiation of nose-cone separation prior to the failure

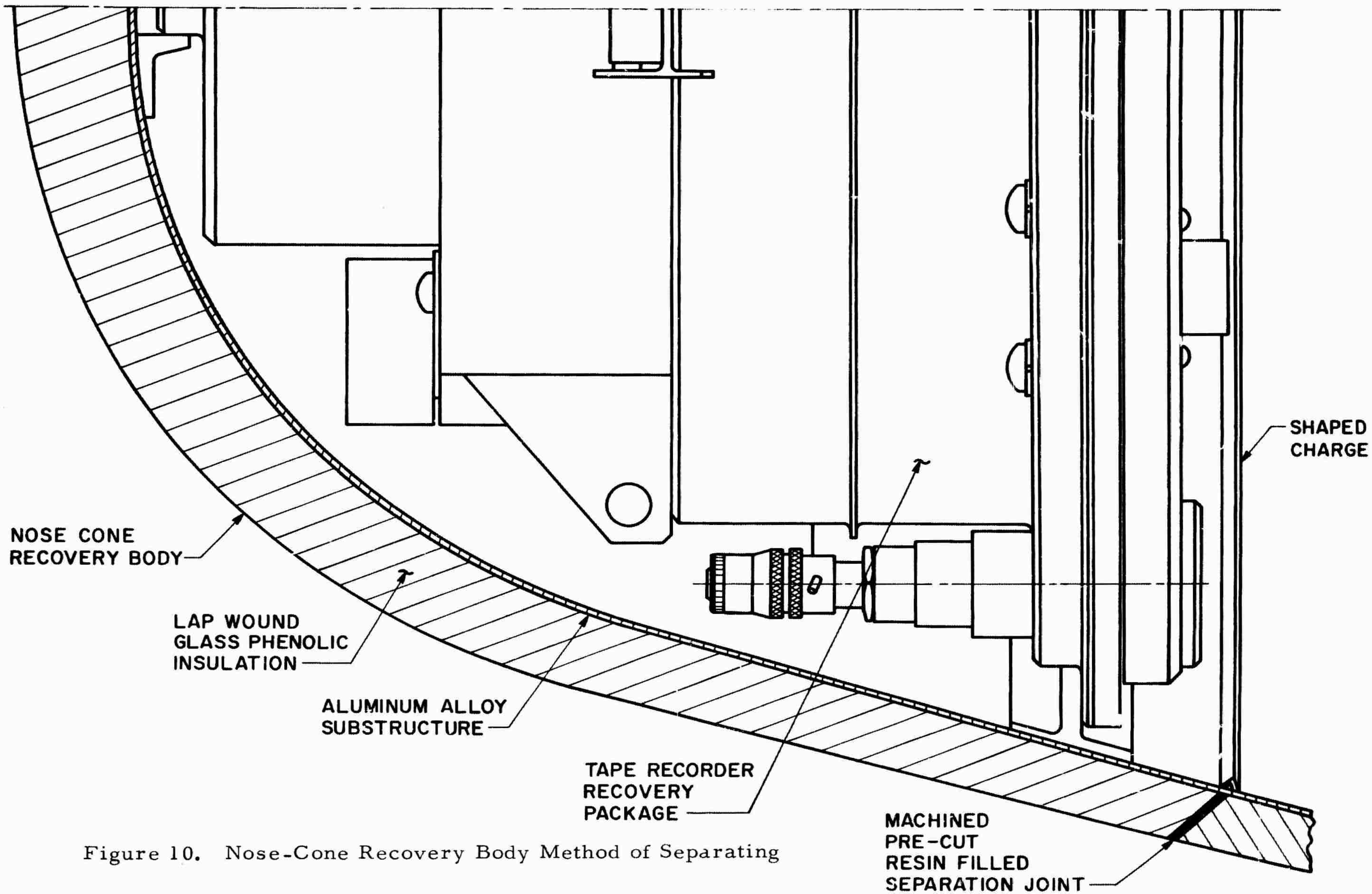


Figure 10. Nose-Cone Recovery Body Method of Separating

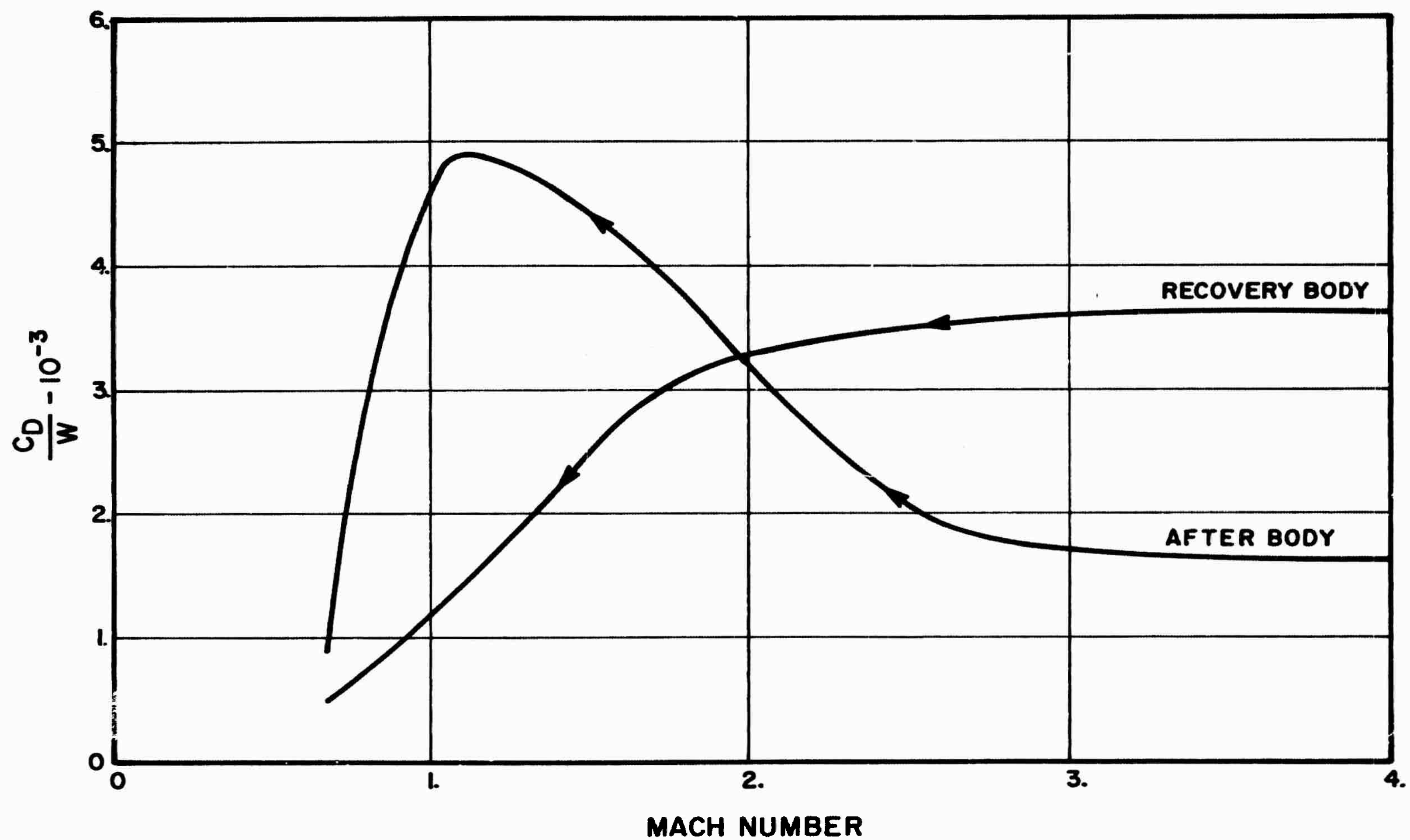


Figure 11. Variation of Recovery Body and Afterbody $\frac{C_D}{W}$ with Mach Number (Zero Angle of Attack)

of the afterbody, proving the ability of the parachute to deploy when the recovery body is in a tumbling mode, and designing the recovery body to avoid static stability in the base-forward flight condition. To give the recovery body adequate stability, a minimum of 1 inch of stability margin was required. Figure 12 gives values for the drag coefficient, C_{D_0}, and center of pressure locations, Xcp, from the nose-cone stagnation point.

The second approach to prevent nose cone tip-off forces at separation was to increase the drag of the afterbody or to employ some method of thrust reversal to separate the nose-cone recovery body from the afterbody to put it out of the influence of the nose cone, so that drag forces can then naturally separate the two bodies.

Banana peeling of the skin and cutting holes in the skin were not considered feasible due to the difficulty of cutting through the insulation material.

Subsequent high-altitude drop tests indicated that the parachute could be deployed when the recovery body was in a tumbling mode. Therefore, it was decided to simply cut the body circumferentially with a shaped charge and allow the recovery body and the aft body to separate under the action of the natural drag forces.

From these studies, the following conclusions were made:

The altitude at which destruction of the afterbody by aerodynamic heating begins is approximately 95, 000 feet.

The steepness of the deceleration-altitude curve indicates that a g-switch would be more feasible in this application, since an extremely sensitive and precise switch would not be necessary. The time-altitude curve is much flatter in the separation area, and thus a timer of high accuracy and adjustable to small increments would be required if a timer is used.

4. Heating Problems

Heat protection for the RTV consists of an aluminum alloy (5052-O) substructure covered by lap-wound glass phenolic. Thicknesses were selected so that the maximum temperature of the inside of the aluminum skin will not exceed 220°F in the area of the recovery body.[9] Table III shows the minimum insulation thicknesses specified for the recovery body. These thicknesses were calculated for the nominal

AMRAD EXP. I RECOVERY BODY DRAG DATA	
BODY WEIGHT	36.00 LB.
BASE DIAMETER	14.59 IN.
REFERENCE AREA	1.161 SQ. FT.
NOSE RADIUS	6.25 IN.
LENGTH	9.65 IN.
FRUSTUM ANGLE	14 DEG.

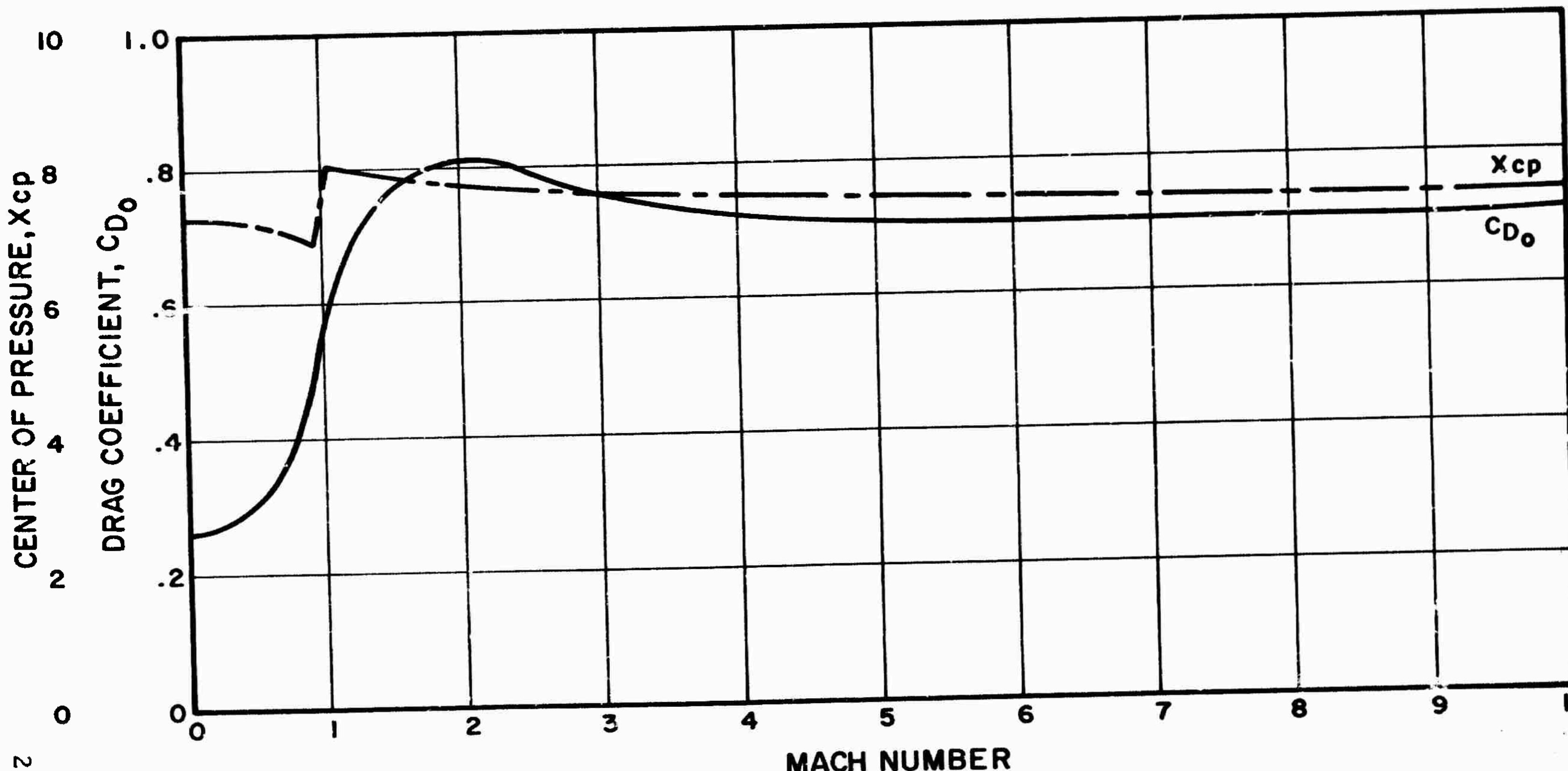


Figure 12. Recovery-Body Drag Data

case of the flight trajectory from the standpoint of heating under the following conditions:

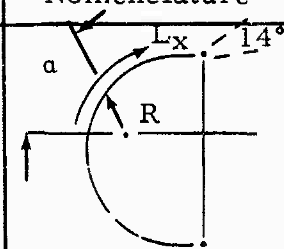
Ballistic Factor, β = 110 lb/ft^2

Re-entry Velocity, V_e = 20,000 ft/sec

Re-entry Angle, θ = 23°

Thermolog T-230 was selected as protection for the RTV cover (bulkhead).

Table III. Insulation and Substructure Skin Thickness

Station	Insulation Thickness (inches)	Aluminum Alloy Thickness (inches)	Nomenclature
α = 0°	0.94	0.054	
α = 30°	0.86	0.054	
α = 76°	0.63	0.054	
L_x = 1 foot	0.56	0.054	
Cover	0.046	0.032	R = 6.25 inches

A study was made to investigate the effects of the expected heat conditions on the heat-sensitive components of the recovery body. Table IV is a list of these components and their recommended maximum heat limitations. Also taken into consideration were their locations within the body, time of operation with relation to the trajectory, and their construction, especially with respect to their material.

Of these, the only critical components were the nickel-cadmium batteries used to fire the power cartridges and operate the flasher system. The other components were either in protected locations, were capable of withstanding 220°F, or had already performed their functions at the time of maximum heating.

The batteries were subjected to heat-chamber tests to determine their ability to withstand high temperature. Tests showed that the batteries were unaffected when exposed to 200° to 250°F temperatures for short periods of time (10 to 14 minutes), and under a steady load of 700 ma. At 180°F, and under a steady load, the batteries operated satisfactorily for 90 minutes. These conditions were more severe than the batteries. In addition, the filled socks were placed inside styrofoam containers that provided at least 1 inch of insulation on all sides.

A modified drop-tank pylon was used on the aircraft as the carrier for the test body. Attachment cables and fittings were provided in the test body. After release of the body from the aircraft, a spring-operated retracting mechanism pulled the cable into the body to prevent interference with the ejection of the cover drag plate. Weight of the test bodies was approximately 43 pounds.

a. Drop Test No. 1.[10]

The first drop test was a daylight test to check out the parachute-recovery system. Failure of one of the two cable attachments to release immediately nearly resulted in a completely unsuccessful test.

When release was attempted, the rear end of the cone (with respect to its mounting position on the aircraft pylon) apparently was released, allowing the main switch to start the timing sequence. The front end of the cone was hung up for approximately 100 seconds. Shortly after the test body was finally shaken loose from the aircraft, the parachute deployed.

Due to the extreme altitude at which the parachute deployed, and the high prevailing wind, the recovery body impacted about 25-miles southeast of the release point after approximately 17 minutes of descent. Ground-based radar tracked the parachute and vectored the recovery aircraft to the impact location.

The parachute-recovery system apparently functioned properly. Average descent velocity was computed to be about 40 feet per second. There was no damage to the body or to the components as a result of impact.

b. Drop Test No. 2.[10]

The second drop test was conducted the early morning hours of darkness. The release system was modified to use better-fitted cable hooks and an ejection spring to push the body away from the wing at release.

Release of the test body was without difficulty and, approximately 100 seconds after release, radar indicated that the parachute had deployed and transmission by the beacon was noted. Radar tracking furnished impact coordinates to the ground and air recovery teams, but recovery had to be delayed until daylight because of darkness (the flasher was not yet developed). Recovery was by the search helicopter.

The radio-tracking information was inadequate as only two (of three) receivers were able to track the test body. However, signal transmission was adequate during descent of the test body.

Total descent time from 45,000-feet altitude was approximately $8\frac{1}{2}$ minutes. The impact point was about 7-miles northeast of the release point. There was no damage to the test body or components.

c. Drop Test No. 3.[11]

The primary objective of this drop test was to evaluate the flashing-light system as a visual location aid. Parachute deployment at 15,000 feet was successful. The flashing light was seen by the search-helicopter pilot when the recovery body was at an altitude of about 4,000 feet. Although this was a moonlit night (3/4 moon), the flashing light on the ground could be plainly seen from the air at a distance of 1 mile.

Operation of the radio-beacon system was not satisfactory. Post-flight cold-chamber tests with the radio-beacon batteries indicated that the polystyrene foam was not adequate protection from extreme cold environments. However, in the actual missile flights this problem would not be experienced.

Section V. CONCLUSIONS

Cancellation of the AMRAD Target Project terminated further high-altitude drop tests, which included separation of the nose-cone recovery body from a mock-up RTV. However, the tests conducted so far indicate the feasibility of the design for use in a nose-cone recovery operation.

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Appendix A
WEIGHT AND BALANCE

Item	Quantity	Weight (lb)
Tape Recorder (less covers)	1	4.033
Explosive-Switch Assembly	1	0.028
Time Assembly	1	0.332
Radio-Beacon Assembly	1	0.596
Radio-Beacon Battery Pack	2	1.536
Batteries, Thruster	4	0.800
Thrusters	2	0.344
Connector Assembly	2	0.076
Parachute Assembly & Swivel (including flasher lamps)	1	3.140
Structure, Internal (nuts, screws, wire, etc.)		6.969
Insulation and Substructure		19.908
Flasher Electronic Unit		0.300
Total Weight		38.062

C. P.	Location from stagnation point at Mach 1 (worst condition)	7.000 inches
C. G.	Location from stagnation point	-5.864 inches
	Stability Margin	+1.136 inches

Appendix B

RECOVERY-BODY OPERATION AND RECOVERY

This appendix describes the operation of the various subsystems of the recovery body and the recovery operation from the time of nose-cone separation to retrieval of the recording tape.

As described in an earlier section in this report, the AMRAD Targets will be flown from the Green River launch complex in Utah to WSMR, where the AMRAD radar system is located. At the launch site, the condition of the timer switch and nickel-cadmium batteries is monitored through two monitoring circuits. The nickel-cadmium batteries can also be recharged through its monitoring circuit. While safing of the motor igniters and g-switch is provided on the ground by a shorting plug, the explosive devices in the recovery body are protected by a "one-shot" explosive switch which is actuated when the g-switch closes.

The sequence of events of the recovery process is as follows:

Event	Remarks
1) G-switch closes	Initiates separation at 100,000-feet (nominal) altitude. Closes circuit to fire timer, dimple motors, explosive switch, and linear shaped charge.
2) Explosive switch closes	Arms power-cartridge circuit.
3) Dimple motors fire	Starts timer operation.
4) Shaped charge fires	Separates nose cone.
5) Timer switch closes	Timer operates for 100 seconds to allow recovery body to descend to 15,000-feet altitude. Closes power-cartridge circuit and actuates flasher-system relay to start flasher system.
6) Power cartridges fire	Actuates thrusters. Electrical power from nickel-cadmium batteries.
7) Thrusters actuate	Ejects recovery-body rear cover to start parachute deployment.

Event	Remarks
8) Rear cover ejects	Ejection force and drag force pull parachute out of container. Also allows radio beacon pop-up antenna switch to extend and switch-on power to beacon.
9) Radio beacon operates	
10) Flasher system operates	
11) Parachute deploys	Initial deployment of parachute in reefed condition to ease opening shock forces.
12) Reefing-line cutters actuate	Allows parachute to disreef.
13) Radar, radio, and search aircraft track recovery body	Initial location of recovery body by radar. Radar control vectors search aircraft to impact area. Aircraft locates and tracks recovery body visually or is directed by main controlling unit from information received by radar and radio tracking.
14) Ground crew starts search	Ground crew attempts location by visual means. Communication between controlling unit and search aircraft is maintained with ground crew.
15) Body recovered	Pick up by search aircraft or ground crew. Recording tape retrieved.

If all the locating aids incorporated in the recovery body fail, information from other means will be used to establish an impact point including ballistic trajectories, impact predictors, and squalene dog-scent. Impact predictors are high-speed computers which use a variety of wind, theoretical, and flight data to predict the impact point. Squalene is a colorless liquid which has an attractive scent for male dogs. It is applied with a brush to the interior of the recovery body at the time of payload assembly. This method has been a significant means at WSMR in the location of missiles and parts which have become separated from missiles at impact. "Scent range" is 400 to 500 yards downwind of the scent source.